TRENCHSTOP™ 5 S5
Infineon’s low $V_{CE(sat)}$ high-speed soft-switching IGBT

About this document

Scope and purpose
This Application Note provides some basic information and some hints on how to deal with Infineon’s HighSpeed IGBT technologies and specifically the newly introduced TRENCHSTOP™ 5 S5 technology which provides unique advantages in terms of $V_{CE(sat)}$, dynamic losses, EMI figures and most important is extremely easy to use.

Intended audience
This Application Note addresses designers that intend to use TRENCHSTOP™ 5 S5 IGBT, especially in industrial and automotive applications. A minimum level of knowledge in electrical design and EMC is required.

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Introduction

The efficient use of electric power is one of the main drivers for progress in power electronics. IGBT technology has supported this trend by providing application specific device optimizations. Figure 1 shows the chronological evolution of Infineon’s IGBT technologies; starting from Punch Through (PT) IGBT, then introducing first Non Punch Through (NPT) IGBT, first FieldStop and Trench cell concepts [1] up to the latest TRENCHSTOP™ 5 Technology [2].

While the main market is still seen in the drives segment, other segments, focusing in the higher switching frequency ranges, gained importance and have further evolved. Among them are photovoltaics, UPS and welding applications that grew to significant size in recent years.

To respond to this increasing demand of higher switching frequency, Infineon has recently released the TRENCHSTOP™ 5 IGBT technology, especially suitable for the above mentioned field of applications.

1.1 TRENCHSTOP™ 5 technology

Starting from the TRENCHSTOP™ Technology, as shown in Figure 1, Infineon TRENCHSTOP™ 5 Technology allows achieving unparalleled switching frequency in the applications. This improvement has been possible thanks to the features, implemented within this new technology [1]:

- Faster turn-off capability due to high holes confinement. The holes are accumulated on the device’s front side, where they have a quicker response at turn-off.
- Lower V_{CE(sat)} and lower E_{on} due to high channel width, thin wafer technology and optimized doping profile.
- Optimized device input capacitance to reduce losses and to improve device controllability in high switching frequency hard switching conditions.

TRENCHSTOP™ 5 IGBT technology is divided according to Figure 2.
TRENCHSTOP™ 5 S5
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The main characteristics of the different products and general advice on most suitable applications are listed in Figure 3. S5 is the latest TRENCHSTOP™ 5 IGBT version which combines low $V_{CE(sat)}$ and competitive switching losses. It is recommended for UPS, welding and solar converters.
Introduction

A rough indication on the typical switching frequencies regarding the different TRENCHSTOP™ 5 IGBT versions is depicted in Figure 4.

![Figure 4](image)

**1.2 Infineon’s TRENCHSTOP™ 5 discrete IGBT product offer**

Figure 5 describes the nomenclature of Infineon’s TRENCHSTOP™ 5 IGBTs. TRENCHSTOP™ 5 H5, F5 and WR5 IGBT product portfolio and Table 2 list the product portfolio of the TRENCHSTOP™ 5 IGBT.

![Figure 5](image)
Introduction

Table 1 describes the H5, F5 and WR5 versions in the packages TO-220, TO-220 Full-Pack (TO-220-FP), TO-247 3pin (TO-247-3) and TO-247 4pin (TO-247-4). Table 2 shows the product portfolio of the S5 and L5 IGBT versions in the packages TO-247-3 and TO-247-4.

### Table 1: TRENCHSTOP™ 5 H5, F5 and WR5 IGBT product portfolio

<table>
<thead>
<tr>
<th>$I_C$ [A] @100°C</th>
<th>TO-220</th>
<th>TO-220-FP</th>
<th>TO-247-3</th>
<th>TO-247-4pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>IKP08N65H5</td>
<td>IKP08N65F5</td>
<td>IKA08N65H5</td>
<td>IKA08N65F5</td>
</tr>
<tr>
<td>15</td>
<td>IKP15N65H5</td>
<td>IKP15N65F5</td>
<td>IKA15N65H5</td>
<td>IKA15N65F5</td>
</tr>
<tr>
<td>20</td>
<td>IKP20N65H5</td>
<td>IKP20N65F5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>IKP30N65H5</td>
<td>IKP30N65F5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>IKP40N65H5</td>
<td>IKP40N65F5</td>
<td></td>
<td></td>
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<tr>
<td>50</td>
<td>IKP50N65H5</td>
<td>IKP50N65F5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>IKP75N65H5</td>
<td>IKP75N65F5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2: TRENCHSTOP™ 5 S5 and L5 IGBT product portfolio

<table>
<thead>
<tr>
<th>$I_C$ [A] @100°C</th>
<th>TO-247-3</th>
<th>TO-247-4pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>IKW30N65ES5</td>
<td>L5</td>
</tr>
<tr>
<td>40</td>
<td>IKW40N65ES5</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>IKW50N65ES5</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>IKW75N65ES5</td>
<td></td>
</tr>
</tbody>
</table>

Regarding TRENCHSTOP™ 5 S5 IGBT, the product portfolio with detailed technical specification of the devices available is listed in Table 3. Testing conditions are given as well.

### Table 3: Detailed technical specifications of the S5 IGBT products

<table>
<thead>
<tr>
<th>Product Part Number</th>
<th>$I_C$ (DC) 100°C [A]</th>
<th>$V_{CE(sat)}$ [V]</th>
<th>$E_{on}$ [mJ]</th>
<th>$E_{off}$ [mJ]</th>
<th>$Q_g$ [nC]</th>
<th>$I_F$ (DC) 100°C [A]</th>
<th>$Q_{rr}$ [µC]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKW30N65ES5</td>
<td>39,5</td>
<td>1,35</td>
<td>0,56</td>
<td>0,32</td>
<td>70</td>
<td>39,5</td>
<td>0,83</td>
</tr>
<tr>
<td>IKW40N65ES5</td>
<td>50</td>
<td>1,35</td>
<td>0,86</td>
<td>0,4</td>
<td>95</td>
<td>50</td>
<td>1,1</td>
</tr>
<tr>
<td>IKW50N65ES5</td>
<td>60,5</td>
<td>1,35</td>
<td>1,23</td>
<td>0,55</td>
<td>120</td>
<td>60,5</td>
<td>1,25</td>
</tr>
<tr>
<td>IKW75N65ES5</td>
<td>80</td>
<td>1,42</td>
<td>1,92</td>
<td>0,95</td>
<td>164</td>
<td>80</td>
<td>1,86</td>
</tr>
</tbody>
</table>

Testing conditions:

- $V_{CE(sat)}$: typ. values, 25°C, $V_{BE}=15$ V, $I_C=I_C(25°C)$
- $E_{on}$ and $E_{off}$: typ. values, 25°C, $V_{CC}=400$ V, $I_C=I_C(25°C)$, $V_{BE}=0/15$ V, $R_G=R_G(nom)$, $L_{G}=30nH$, $C_{G}=30pF$
- $Q_g$: typ. values, 25°C, $V_{BE}=520$ V, $V_{BE}=15$ V, $I_C=I_C(25°C)$
- $Q_{rr}$: typ. values, 25°C, $V_{BE}=400$ V, $I_C=I_C(25°C)$, $dI_C/dt=1.2kA/\mu s$ for the 30 A and 50 A, $=0.8kA/\mu s$ for the 40 A, $=1.5kA/\mu s$ for the 75 A
1.3 Description of the TRENCHSTOP™ S5 IGBT and main differences compared to other TRENCHSTOP™ 5 IGBT versions

S5 TRENCHSTOP™ 5 IGBT is the new soft switching and low $V_{CE(sat)}$ IGBT version intended to operate between 15 kHz to 30 kHz with the possibility to approach the 40 kHz range. It also features:

- Soft and smooth switching behavior, still maintaining very competitive switching performances
- Easy to use; with the new S5 IGBT it is possible to do a 1:1 replacement of the former IGBT technologies with a very low $Q_g$
- Very low $V_{CE(sat)}$
- Full rated fast freewheeling diode
- Improved FB-SOA, reaching $4 \times I_{Cp(n)}$
- 100% dynamic test performed

TRENCHSTOP™ S5 exploits the same technological approach of the former H5 version, but it uses a stronger annealed backside emitter. This allows reaching a similar switching performance as the H5 IGBT, thanks to a very simple gate resistance adjustment. This is due to a much softer behavior both in turn-on and turn-off with reduced $dv/dt$ and $di/dt$ at nominal load and even at partial load conditions.

Although switching losses using nominal gate resistors are slightly increased in respect to the H5, the softer commutation behavior of the S5 allows using a much smaller gate resistance keeping the same voltage overshoot at turn-off in case of bad layout with large stray inductance. In such cases, it is possible to maintain similar switching losses with respect to the H5 and still get a large benefit in total losses reduction due to the significant reduction of the forward voltage $V_{CE(sat)}$ of $\sim 18\%$. Compared to the 1.65 V of the H5, S5 exhibits a value of 1.35 V only.

The main differences between the new S5 IGBT version and the other TRENCHSTOP™ 5 IGBT variants suitable for industrial and consumer markets are:

**WR5**
- It is the price optimized application specific TRENCHSTOP™ 5 IGBT for resonant applications like Zero Current Switching (ZCS) with a monolithically embedded diode. It is suitable for welding applications, Single-Phase PFC and Boost topologies, especially in Discontinuous Conduction Mode (DCM) of operation. WR5 needs a split gate resistance $R_{G(on)}$ and $R_{G(off)}$ and eventually clamping circuitry; it offers excellent performance when used in very low stray inductive environments in the range of 10 to 30 nH in both, power- and gate-path.

**L5**
- is the extremely-low $V_{CE(sat)}$ TRENCHSTOP™ 5 IGBT offering uncomparable $V_{CE(sat)}$ value, down to 1.05V. It is a good fit in combination with Rapid 1 diodes; in general to be used in Three-Level topologies as inner switch, especially at $\cos(\phi)$ between 0.8 and 1. It is suitable mainly for solar inverters, but might be also used in UPS systems. It can also be used as unfolding switch device in 50Hz applications like SCR and Thyristors replacement and also in the secondary inverter for Al/Mg Welding machines or even as DC circuit breaker.

**H5**
- provides a very fast version of the TRENCHSTOP™ 5. It is intended to be used in industrial applications like welding, UPS and solar and in general addresses applications having a layout with a total stray inductance less than 30…80 nH. It is co-packaged with Rapid 1 diodes and can also be used in combination with Rapid 2-diodes or with SiC Shottky Barrier Diodes (SBD) to dramatically reduce turn-on losses.

**F5**
- Poses the ultra-fast version, best fit in combination with Rapid 2 diode or SiC SBD; it needs a split gate resistance: $R_{G(on)}$ and $R_{G(off)}$ and in general is designed for applications having excellent layout routing with a total stray inductance less than 10…30 nH.
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Infineon’s low $V_{CE(sat)}$ high-speed soft-switching IGBT

**Introduction**

In Table 4, the main difference in terms of characteristics between the different TRENCHSTOP™ 5 technologies are quantified specifically for a 50 A 650 V/600 V IGBT. This includes the new S5 and the former IGBT TRENCHSTOP™ technologies. This size is not available as L5 IGBT. Therefore a 30 A IGBT has been considered as reference with parameters related to the nominal current.

### Table 4 Comparison Table between HighSpeed 3 IGBT Technology and TRENCHSTOP™ 5 IGBT versions

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>IGBT 3 cell</th>
<th>TRENCHSTOP™ 5 cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{C(n)}$ [A]</td>
<td>IGBT3</td>
<td>HS3</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>FB-SOA</td>
<td>3x$I_{C(n)}$</td>
<td>4x$I_{C(n)}$</td>
</tr>
<tr>
<td>$V_{BR(CES)}$ [V]</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>$V_{CE(sat),typ}$ @ $T_{j}=25^\circ C$ [V]</td>
<td>1.50</td>
<td>1.65</td>
</tr>
<tr>
<td>$V_{CE(sat),typ}$ @ $T_{j}=125^\circ C$ [V]</td>
<td>1.80</td>
<td>1.70</td>
</tr>
<tr>
<td>$E_{on}$ @ $I_{C(n)}$, 150°C, 10 Ω, typ [mJ]</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>$E_{off}$ @ $I_{C(n)}$, 150°C, 10 Ω, typ [mJ]</td>
<td>1.7</td>
<td>1.1</td>
</tr>
<tr>
<td>SC Rating [μs]</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>$I_{C(SC)}$</td>
<td>9x$I_{C(n)}$</td>
<td>6.5x$I_{C(n)}$</td>
</tr>
</tbody>
</table>

(*) 4x$I_{C(n)}$ available for specific applications. (**) $R_G=20$ Ω.

TRENCHSTOP™ 5 H5 IGBT is indeed an extremely fast device in turn-off, but it requires some effort and experience in layout designs to avoid excessive voltage overshoots in turn-off and possible challenges in terms of EMC. This effort is no longer necessary when using the S5 version, thanks to the reduced $di/dt$ in turn-on and $dv/dt$ in turn-off which are much easier adjustable via gate resistance compared to the H5 version. Furthermore, even in non-perfect layouts, a direct replacement of HighSpeed 3 and former TRENCHSTOP™ technology is now possible.
2 S5 IGBT static performances

TRENCHSTOP™ 5 S5 IGBT reveals a very low saturation voltage, which is dramatically improved in comparison to the fast TRENCHSTOP™ 5 versions H5 and F5. The forward voltage $V_{CE(sat)}$ has been reduced from the typical 1.65 V of the H5 down to the typical 1.35 V of the S5.

A further important advantage regarding H5 and F5, which is intrinsic in the S5 technology, is the narrower $V_{CE(sat)}$ distribution. Figure 6 depicts the typical and maximum values for $V_{CE(sat)}$ of the 40 A H5 and F5 IGBT respect to the analogous 40 A S5.

From this improved characteristic derive, from static point of view, a very stable static performance and a simple and more efficient paralleling of the devices.

<table>
<thead>
<tr>
<th>IGBT Type</th>
<th>$V_{CE(sat)}$ [V]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKW40N65ES5</td>
<td>1.2</td>
</tr>
<tr>
<td>IKW40N65H5</td>
<td>1.4</td>
</tr>
<tr>
<td>IKW40N65F5</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Figure 6 $V_{CE(sat)}$ at 25°C, typical and maximum values

3 Switching performances

High speed technology does not automatically mean best performance in real applications. It should be considered that in most of the cases it is not always possible to simply replace the former Infineon Technologies, without any layout improvement. This is especially true when using the fast TRENCHSTOP™ 5 IGBT versions like F5, WR5 and H5. In such cases, PCB layout design must have an extremely narrow current compensation path to get the lowest parasitic inductance in both, power- and signal-path. Alternatively, specific gate network or split gate resistances are required.

All these arrangements are obsolete with the new S5 IGBT. This technology allows a simple 1:1 replacement with the former HighSpeed 3 technology, even using the same gate resistance. No need of complicated passive gate networks, no expensive clamping circuitry on the collector.

An example of the different dynamic behavior is reported in the Figure 7 and Figure 9. Figure 7 shows a direct comparison of the turn-off behavior of an S5 in comparison with an H5 and to a former TRENCHSTOP™ IGBT in a double pulse test having a stray inductance of about 35 nH. The junction temperature is $T_{j}=25^\circ C$ and the gate resistance is $R_g=10.2 \, \Omega$ in both cases. Solid lines depict the H5 behavior, dashed lines show the S5 and dotted lines finally show the former Trench IGBT dynamic behavior in turn-off.
Collector current of the S5 shows a lower di/dt, which leads to a reduction of the overshooting voltage of about 70 V in this case. In Figure 8, we have collector current $I_C$, 10 A/div. Collector to Emitter voltage, $V_{CE}$, 100 V/div. Gate to Emitter voltage, $V_{GE}$, 10 V/div. turn-off switching losses, $E_{off}$ 100 µJ/div. Time scale 100 ns/div.

The same behavior is reported in real applications. Tests have been carried out on IKW40N65ESS measured using an in-house welding test bench as can be seen in Figure 8. It is a single phase Manual Metal Arc (MMA) welding machine 4.5 kW Infineon-TF1 Half-Bridge testing demonstrator at $L_s=90$ nH and $f_{sw}=38$ kHz. Testing conditions include: $T_{amb}=23^\circ$C, $T_{j}=T_{amb}$, $R_{g(on)}=22$ Ω, $R_{g(off)}=33$ Ω, $I_{out}=157$ A, $I_C=33$ A.

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**Figure 7**  Switching behaviour comparison between IKW50N65H5, solid lines, IKW50N65ESS, dashed lines, and IKW50N60TA, dotted lines

**Figure 8**  Infineon-TF1 4.5kW half-bridge, MMA/TIG welding machine demonstrator
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Switching performances

The switching behavior is displayed in Figure 10. $I_C$, $V_{CE}$ and $V_{GE}$ waveforms in a time scale of 100 ns for a fast WR5 IKW40N65WR5 and the equivalent S5 version IKW40N65ES5 are compared. Voltage overshooting has been reduced, in the same testing condition, by about 35%. Beside this difference, another relevant aspect to be noted is the characteristic of the overshooting and the lower $dv/dt$, with about 30% reduction. $I_C$ at 10 A/div. $V_{CE}$ at 100 V/div. $V_{GE}$ at 7 V/div. $P_D$ at 2 kW/div. $E_{off}$ is calculated as integral of the Power $P_D$ and the result is detailed in the chart. Time scale for all waveforms is $t=100$ ns/div.

![Figure 9](image1.png)  
**Figure 9** Comparison of the switching behavior between (a) IKW40N65WR5 and (b) IKW40N65ES5.

Another comparison is shown in Figure 11. $I_C$, $V_{CE}$ and $V_{GE}$ behavior in a time scale of 100ns related to two competitors’ devices from top to bottom, Comp1 and Comp2 and the equivalent S5 version IKW40N65ES5 are highlighted. $I_C$ at 10 A/div; $V_{CE}$ at 100 V/div; $V_{GE}$ at 7 V/div; $P_D$ at 2 kW/div, $E_{off}$ is calculated as integral of the power $P_D$ and the result is depicted in the chart. A strong reduction in the voltage peak during turn-off can be noted. The softer behavior of the voltage overshoot at turn-off and the lower slew rate are even more evident than in the case of Figure 10.

![Figure 10](image2.png)  
**Figure 10** Comparison of the switching behavior between two competitors’ devices and an IKW40N65ES5 (from top to bottom)
3.1 Safe operating areas

As per IEC 60747 3.3.14, Safe Operating Areas (SOA) is a chart of collector current versus collector emitter voltage where the IGBT is able to turn-on and turn-off without failure. It is possible to distinguish:

- Forward bias safe operating area (FBSOA), as per IEC60747-9 3.3.14.1. This is the collector current versus collector emitter voltage area which the IGBT is able to turn-on and is able to be in on-state without failure.
- Reverse bias safe operating area (RBSOA) as per IEC 60747-9 3.3.14.2. is the collector current versus collector emitter voltage area where the IGBT is able to turn-off without failure.
- Short Circuit safe operation area (SCSOA)

Figure 11(a) display the Forward Bias Safe Operating Area (FBSOA) of an IKW50N65H5.

Although short excursions into the active region might be allowed within TRENCHSTOP™ 5 technologies, it is strongly recommended to operate these IGBT families as a switch-mode only and to use it in active region only during commutation transients. Indeed, it is not recommended to operate TRENCHSTOP™ 5 IGBT continuously in linear- or active amplification mode, to avoid local overload due to the variation in the transfer characteristic of the IGBT cells or paralleled chips. Therefore, the diagonal lines - at constant power dissipation per pulse duration and especially the DC-mode operation typical for the former IGBT technologies are no longer suggested as continuous working conditions. For the S5 version the FBSOA chart is no longer available since it is considered a full square, limited by the maximum forward power dissipation, caused by $V_{CE(sat)}$ and by the $I_{C(pulse)}$ limited by $T_{vj(max)}$.

In such case for the S5 version, due to additional specific measures, the FBSOA has been extended up to 4 times the nominal collector current; while for the H5 version, this is only performed upon specific requests.

Figure 11

(a) IKW50N65H5 Forward Bias Safe Operating Area. (b) Reverse Bias Safe Operating Area (RBSOA), showing the limitations introduced by collector to emitter parasitic inductance -in this case considering a layout with total $L_c=40$ nH.

Figure 11 (b) depicts an example of a Reverse Bias Safe Operating Area (RBSOA). Also in this case, for the S5 version, the RBSOA has been extended up to four times the nominal current. Indeed, TRENCHSTOP™ 5 IGBT technology may operate at max $I_c$ up to three times the nominal current. However, due to the stray inductance limitations, it might be not possible to turn-off without maximum $V_{CES}$ being exceeded. In this
case, a layout with a total stray inductance of $L_s=40\ \text{nH}$ has been considered. This leads to potential SOA limitations, especially when running large current and high level of fall times, in general with $\text{di/dt}$ at above $3...7\ \text{kA/\mu s}$.

Such current levels in the H5, F5 and WR5 versions might be achieved only using adequate layout solutions or appropriate countermeasures like layout improvements, reduced DC Link voltage, introduction of active clamping, using larger $R_o$ - slower and softer turn-off and/or only in case no other countermeasures work, using specific turn-off stress relief circuits. All these arrangements might not be necessary when using an S5 IGBT version, having lower $\text{di/dt}$ and therefore self-limiting characteristics regarding the voltage overshoots at turn-off.

4 Application example, design hints and recommendations using the TRENCHSTOP™ 5 S5 IGBT version

As mentioned in Chapter 3, TRENCHSTOP™ 5 S5 exploits the same technological approach as the former H5 version but it uses a backside emitter that experienced stronger annealing. This allows reaching similar switching performance as the H5 IGBT, thanks to a simple gate resistance adjustment due to the much smoother behavior.

Although switching losses using the nominal gate resistor $R_o$ are slightly increased compared to the H5, the softer commutation behavior of the S5 allows using a much smaller gate resistance keeping the same voltage overshoot at turn-off. In such case, it is possible to maintain similar switching losses in comparison with the H5 and to get a large benefit in total losses reduction due to the significant reduction of the forward voltage $V_{\text{CE(sat)}}$ by $18\%$; the value changes down to $1.35\ \text{V}$ against the $1.65\ \text{V}$ of the H5. To maintain a maximum voltage overshoot of $80\% \times V_{\text{BR(CE)}}$ or $520\ \text{V}$, the H5 would require a gate resistance of $27\ \Omega$, as seen in Figure 12(a), while the S5 only a $4.7\ \Omega$. In such conditions, as shown in Figure 12(b), the turn-off losses will result in the range of $1.2\ \text{mJ}$ for the S5 and about $1.3\ \text{mJ}$ for the H5. The turn-on losses of the S5, as shown in Figure 12(c), will be reduced in comparison to the H5 by about $42\%$. This leads to a significant reduction in the total losses for the S5 by about $26\%$.

![Graphs](image)

**Figure 12** Selection of a lower gate resistance value with S5 is possible compared to H5. (a) $V_{\text{CE(max)}}$ is set at $520\ \text{V}$, it is possible to select $4.7\ \Omega$ for the S5 and $27\ \Omega$ for the H5. Using these $R_o$ values, the S5 has $8\%$ lower $E_{\text{off}}$ (b) and $42\%$ lower $E_{\text{on}}$ (c).

The simplification of the input circuitry, using a single gate resistance approach, is depicted in Figure 13. Figure 13(a) displays a recommended solution with a possible clamping network and eventual electrical stress relief circuitry to be placed as close as possible to the IGBT/FWD for the IKW50N65H5 and the related PCB routing circuitry. Figure 13(b) describes the single gate resistance approach for a typical S5 application and the simplification of the PCB routing which is possible to achieve with S5 accordingly.
Another important aspect, relevant in several applications, is related to the case of large currents commutated in very short time. This is only the case with the IKW75N65ES5 when used with very large collector currents and when using a small gate resistance.

In this situation, the $di/dt$ in turn-on, due to very short rise time, might be extremely high and result in a challenge for the Rapid 1 diode in antiparallel used for free-wheeling. In this extreme situation and only for this component of the S5 series, it is recommended to split the gate resistance in $R_{G(on)}$ and $R_{G(off)}$, increasing the $R_{G(on)}$ in comparison to the suggested nominal gate resistance value.

The value of this resistance is related to the stray inductance of the circuit and to the $di/dt$ reached during the commutation. For a parasitic inductance of $30...40$ nH, it is recommended to increase the gate resistor $R_{G(on)}$ up to 3 times the nominal gate resistance value, while for a stray inductance above $50...60$ nH, an increase of $R_{G(on)}$ up to 5 times might be necessary.

Figure 14 (c) displays an example of a switching event using a IKW75N65ES5 which is commutating a collector current of 225 A representing three times the nominal current with a gate resistance of $1.7 \Omega$ in a very low stray inductance environment of about 30 nH. Figure 14(b) the same characteristics is depicted, using a gate resistance of $40.6 \Omega$. In order to compensate the obvious increase in the switching losses, in this case about 34%, it is suggested to split the gate resistance and to select the nominal $R_0$ value for the turn-off: $R_{G(off)}$. In this case the circuit is sketched in Figure 14 (a).
Finally, as with other TRENCHSTOP™ 5 technologies, it is worth to mention the minimum turn-on time to avoid EMI problems. To reach a relatively soft switching, the charge carriers of a bipolar device like diode, BJT or IGBT, must be granted sufficient time to reach the state of quasi-static charge carrier distribution. This is not the case for very short conduction times. The high-frequency oscillations which may be triggered because of this reason can influence signals and logic devices. This may significantly impair a safe and reliable operation. Furthermore it should be considered that, owing to the lower mobility of charge carriers, this effect is particularly strong at high temperatures, especially when approaching the 150°C junction temperature.

Unfortunately in a data sheet for a discrete component, the minimum turn-on time cannot be specified like in a power module for example, as the magnitude and the frequency of the oscillations strongly depends on the parasitic components of the PCB routing itself. This mainly considers the stray inductances but parasitic capacitances and resistances as well. As a very general recommendation when using TRENCHSTOP™ 5 S5 IGBT version, it is suggested to cancel extremely short pulse signals in the PWM pattern, especially the ones well below 1 μs.
5 References


6 Useful material and links

IGBT web page: [http://www.infineon.com/igbdiscreses](http://www.infineon.com/igbdiscreses)
  - Contains application note and spice models for discrete IGBT

TRENCHSTOP™ 5 S5 web page: [http://www.infineon.com/trenchstop5-S5](http://www.infineon.com/trenchstop5-S5)
  This page will include:
  - Product Technical Description
  - Use in Application
  - Assembly Details
  - Product Brief
  - Datasheets
## 7 Revision History

### Major changes since the last revision

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